

Chemical Equilibrium - 2

1. The gaseous reaction $A + B \rightleftharpoons C + D + \text{heat}$ has reached equilibrium. It is possible to make the reaction to proceed forward

- 1) By adding more of C
- 2) By adding more of D
- 3) By raising the temperature of the system
- 4) By lowering the temperature

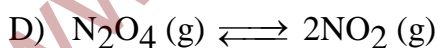
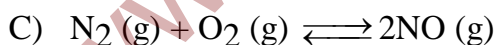
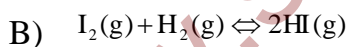
Hint: \therefore it is an exothermic reaction.

2. Given the reaction $2X(g) + 2Y(g) \rightleftharpoons Z(g) + 80 \text{ k.cals}$, which combination of pressure and temperature gives the highest yield of Z at equilibrium

- 1) 1000 atm and 500°C
- 2) 500 atm and 500°C
- 3) 1000 atm and 100°C
- 4) 500 atm and 100°C

Hint: Forward reaction is favored by Low temperature \therefore it is an exothermic reaction and High 'P' as no. of moles decreases.

3. In which of the equilibrium, the position of the equilibrium shifts towards products, if the total pressure is increased



- 1) B 2) C 3) A 4) D

Hint: Increase of pressure shifts the reaction in the direction of decrease in moles.

4. The degree of dissociation of PCl_5

- 1) Increases with increasing pressure
- 2) Decreases with increasing pressure
- 3) No effect on change in pressure
- 4) Decreases with decreasing pressure

Hint: Dissociation of PCl_5 involves increase of moles

5. In which of the following systems, doubling the volume of the container causes a shift to right?

- 1) $\text{H}_2 (\text{g}) + \text{I}_2 (\text{g}) \rightleftharpoons 2\text{HI} (\text{g})$
- 2) $2\text{CO} (\text{g}) + \text{O}_2 (\text{g}) \rightleftharpoons 2\text{CO}_2 (\text{g})$
- 3) $\text{N}_2 (\text{g}) + 3\text{H}_2 (\text{g}) \rightleftharpoons 2\text{NH}_3 (\text{g})$
- 4) $\text{PCl}_5 (\text{g}) \rightleftharpoons \text{PCl}_3 (\text{g}) + \text{Cl}_2 (\text{g})$

6. In the dissociation of CaCO_3 in a closed vessel, the forward reaction is favoured by

- 1) Adding of more CaCO_3
- 2) Removal of some CaO
- 3) Increasing the pressure
- 4) Decreasing the pressure by removing some CO_2 from the equilibrium mixture

Hint: Removal of product favours the forward reaction. Addition and removal of a solid has no effect.

7. In the reaction $\text{NH}_4\text{HS}(\text{s}) \rightleftharpoons \text{NH}_3 (\text{g}) + \text{H}_2\text{S} (\text{g})$ on doubling the concentration of ammonia the equilibrium concentration of H_2S

- 1) Is reduced to half its initial value
- 2) Increases by two times
- 3) Remains unchanged
- 4) Increases by four times

Hint: Increase of products concentration favours the backward reaction

8. In a gaseous reaction $2A \rightleftharpoons 3B$ on doubling the volume of container the equilibrium amount of the product

- 1) Increases 2) Decreases 3) Remains same 4) Data Insufficient

Hint: Doubling the volume of container, Pressure decreases. Decrease of pressure shifts the reaction in the direction of increase in moles.

9. Manufacture of ammonia by Haber's process involves the reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3 = -22.4 \text{ k cal}$. The effect of increase of temperature on the equilibrium is

- 1) Equilibrium is shifted to the right
2) Equilibrium is unaffected
3) Equilibrium is shifted to the left
4) Equilibrium is shifted first to right then to left

Hint: Increase of pressure shifts the reaction in the direction of decrease in moles.

10. Backward reaction is favoured by increase in the pressure of the equilibrium

- 1) $2SO_2 + O_2 \rightleftharpoons 2SO_3$ 2) $N_2 + O_2 \rightleftharpoons 2NO$
3) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ 4) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

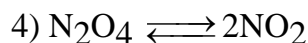
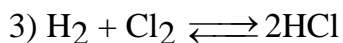
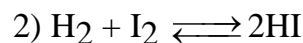
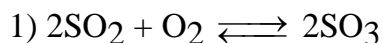
Hint: Increase of pressure shifts the reaction in the direction of decrease in moles.

11. In the manufacture of NH_3 , which are favourable conditions?

- 1) High pressure and low temperature
2) High pressure and high temperature
3) Low pressure and low temperature
4) Low pressure and high temperature

Hint: $N_2 + 3H_2 \rightleftharpoons 2NH_3$ $\Delta H = -92 \text{ KJ/mole}$. Forward reaction is exothermic and involve decrease of moles.

12. In which of the following equilibrium reaction the equilibrium would shift to the right, if pressure is increased



Hint: Ans; 1. \therefore No. of moles decreases in forward reactin.

13. The equilibrium concentration of C_2H_4 in the following reaction can be increased by $\text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g}) \rightleftharpoons \text{C}_2\text{H}_6(\text{g}); \Delta\text{H} = -31.7 \text{ K.Cal}$

1) Removal of C_2H_6

2) Addition of H_2

3) Increase in temperature

4) Increase in pressure

14. Ammonium chloride dissolves in water with the absorption of heat. Which of the following is true?

1. The solubility of ammonium chloride decreases with increase in temperature

2. The solubility of ammonium chloride increases with increase in temperature

3. At higher temperature, ammonium chloride in solution exists as ammonia and Hydrochloric acid

4. At lower temperature ammonium chloride in solution is present in the molecular form

Hint: As dissolution is endothermic, high temperature favours solubility.

15. For the reaction $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$ at 721K, the value of equilibrium constant is 50. The value of K_p under the same conditions will be

1) 0.02

2) 0.2

3) 50

4) $50/RT$

Hint; $K_p = K_c$ as $\Delta n = 0$.

16. The effect of increasing the pressure on the following gaseous equilibrium $2\text{A} + 3\text{B} \rightleftharpoons 3\text{C} + 2\text{D}$ is

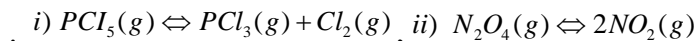
1) Favours forward reaction

2) Favours backward reaction

3) No effect

4) Favours for forward and backward reaction

17. Consider the reactions



The addition of an inert gas at constant volume:

- 1). Will increase the dissociation of as well as
- 2). Will reduce the dissociation of as well as
- 3). Will increase the dissociation of and step up the formation of
- 4). Will not disturb the equilibrium of the reactions

Hint: At constant volume addition of inert gas not disturb equilibrium state.

18. In a reaction $A_2(g) + 4B_2(g) \rightleftharpoons 2AB_4(g)$; $\Delta H < 0$, the formation of $AB_4(g)$ will be favoured at

- 1) Low temperature and high pressure
- 2) High temperature and low pressure
- 3) Low temperature and low pressure
- 4) High temperature and high pressure

19. In the equilibrium $4H_2O(g) + 3Fe(s) \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$ the yield of H_2 can be increased by

- 1) Increasing the pressure
- 2) Passing more steam
- 3) Increasing the mass of iron
- 4) Decreasing the pressure

20. LeChatelier's principle is applicable to

- | | |
|-----------------------------|-----------------------------|
| 1) Chemical equilibria only | 2) Physical equilibria only |
| 3) Both 1 & 2 | 4) Neither 1 nor 2 |

21. The molar concentrations of A, B and C at equilibrium for the reaction

$A + 2B \rightleftharpoons 3C$ are 2, 3 and 4 moles/ lit respectively. Its K_c is

- 1) 2 2) 3.56 3) 0.2 4) 0.026

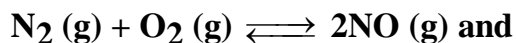
Solution:
$$K_c = \frac{[C]^3}{[A][B]^2}$$

22. The equilibrium constant K_c of a reversible reaction is 10. The rate constant for the reverse reaction is 2.8. What is the rate constant for the forward reaction?

- 1) 0.28 2) 28 3) 0.028 4) 280

Solution: $K_c = K_f/K_b$

23. The equilibrium constants for the reactions



$\text{NO}(\text{g}) + 1/2 \text{O}_2(\text{g}) \rightleftharpoons \text{NO}_2(\text{g})$ are K_1 and K_2 respectively. Then the equilibrium constant for the reaction $\text{N}_2(\text{g}) + 2\text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$ is

- 1) K_1/K_2 2) $K_1^2 - K_2^2$ 3) $K_1 K_2^2$ 4) K_1/ K_2^2

Solution; Multiply the second equation with (2) and then add both.

24. For the reaction $\text{C}(\text{s}) + \text{CO}_2(\text{g}) \rightleftharpoons 2\text{CO}(\text{g})$, the partial pressures of CO_2 and CO are 4.0 and 4.0 respectively at equilibrium, what is the value of K_p for this reaction

- 1) 0.5 2) 1.0 3) 4.0 4) 32

Solution:
$$K_p = \frac{P_{\text{CO}}^2}{P_{\text{CO}_2}}$$

25. The K_c for the reaction $\text{A} + \text{B} \rightleftharpoons \text{C}$ is 4 and K_c for $2\text{A} + \text{D} \rightleftharpoons \text{C}$ is 6 the value of

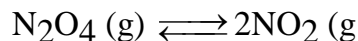
K_c for $\text{C} + \text{D} \rightleftharpoons 2\text{B}$ is

- 1) 0.67 2) 0.375 3) 2.7 4) 1.5

Solution; Equation 2 - 2X Equation 1. i.e. $K_c = K_2/K_1^2 = 6/4^2 = 6/16 = 0.375$

26. The equilibrium constant for the reaction

$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$ is 81 at a certain temperature. If the concentrations of H_2 and I_2 are 3 mole / lit each at equilibrium, the equilibrium concentration of HI is



Initial	0.1	0
Reacted & Formed	0.05	0.1
At equilibrium:	0.05	0.1

$K_C = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = \frac{[0.1]^2}{[0.05]} = 0.2$

30. 1 mole of A (g) is heated to 300⁰ C in closed one litre vessel till the following equilibrium is reached $\text{A} (\text{g}) \rightleftharpoons \text{B} (\text{g})$ The equilibrium constant for the reaction at 300⁰C is 4. What is the concentration of B (in mol. lit⁻¹) at equilibrium?

- 1) 0.2 2) 0.6 3) 0.8 4) 0.1

Solution:

$\text{A} (\text{g}) \rightleftharpoons \text{B} (\text{g})$		
Initial	1	0
Reacted & Formed	x	x
At equilibrium:	1-x	x

$K_C = \frac{[\text{B}]}{[\text{A}]}, 4 = \frac{x}{1-x}$
 $4[1-x] = x, 5x=4$ and $x=4/5=0.8$

31. PCl_5 was taken at 2 atm in a closed vessel at 154⁰C. Keeping the temperature constant $\text{PCl}_5 \rightleftharpoons \text{PCl}_3 + \text{Cl}_2$ equilibrium is established when 50% of PCl_5 decomposes. The K_p for the equilibrium is

- 1) 1atm 2)3atm 3)1.5atm 4)0.5atm

Solution:

$\text{PCl}_5 \rightleftharpoons \text{PCl}_3 + \text{Cl}_2$			
1 mol	0 mol	0 mol	at start
0.5 mol	0.5 mol	0.5mol	at equilibrium

The pressure at equilibrium $= 2 \times \frac{1.5}{1} = 3 \text{ atm}$

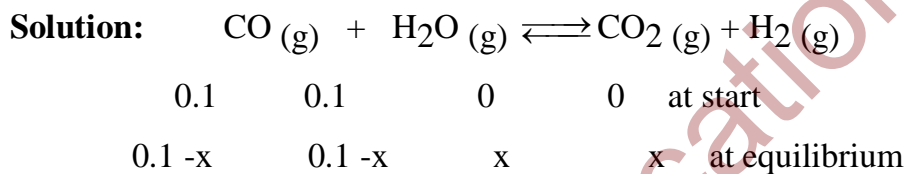
The partial pressures; $P_{\text{PCl}_5} = 3 \times \frac{0.5}{1.5} = 1 \text{ atm}$, $P_{\text{PCl}_3} = 3 \times \frac{0.5}{1.5} = 1 \text{ atm}$

and $P_{Cl_2} = 3 \times \frac{0.5}{1.5} = 1 \text{ atm}$

The equilibrium constant, $K_p = \frac{P_{PCl_3} P_{Cl_2}}{P_{PCl_5}} = \frac{1 \times 1}{1} = 1 \text{ atm.}$

32. The reaction was started with 0.1M each of CO and H₂O at 800K. K_C for the reaction $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$, at 800K is 4.24. What is the equilibrium concentration of the lightest gas?

- 1) 0.933M 2) 0.067M 3) 1.067M 4) 0.1M



The equilibrium constant K_C is given as, $K_c = \frac{[CO_2][H_2]}{[CO][H_2O]} = \frac{x^2}{(0.1-x)^2} = 4.24$

$3.24x^2 - 0.848x + 0.0424 = 0$, $3.059x = 0.2059$. Concentration of H₂ = x = 0.067M.

33. K_p for the reaction, $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$, at certain temperature is 4 bar². The equilibrium pressure of mixture is

- 1) 16bar 2) 8bar 3) 2bar 4) 4bar

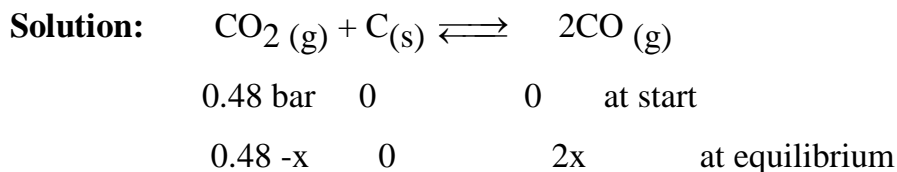
Solution: Equilibrium constant, $K_p = P_{NH_3} \times P \text{ of } H_2S$

Partial pressures are given as, $P_{NH_3} = P_{H_2S} = \sqrt{9} = 3\text{bar}$

Total pressure at equilibrium is obtained using Dalton's law of partial pressures as, $P_{NH_3} + P_{H_2S} = 3 + 3 = 6\text{bar.}$

34. Calculate the ratio of pressures of CO₂ gas and CO gas at equilibrium in the reaction $CO_2(g) + C(s) \rightleftharpoons 2CO(g)$, if K_p is 3 bar at 900K and initial pressure of CO₂ is 0.48 bar.

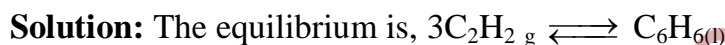
- 1)1.2 2)0.75 3)0.557 4) 1.732



$$K_p = \frac{P_{\text{CO}}^2}{P_{\text{CO}_2}} = \frac{(2x)^2}{(0.48-x)} = 3 \Rightarrow \frac{2x}{0.48-x} = 1.732 \quad \frac{P_{\text{CO}_2}}{P_{\text{CO}}} = \frac{0.48-x}{2x} = \frac{1}{1.732} = 0.557$$

- 35. For the cyclic trimerisation of acetylene to give one mole of benzene, $K_c = 64 \text{ L}^2\text{mol}^{-2}$. If the equilibrium concentration of benzene is 1.0 mol L^{-1} , The equilibrium concentration of acetylene is**

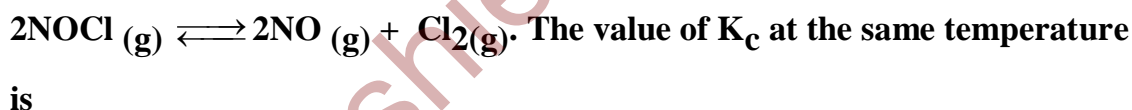
- 1)0.25M 2) 0.5M 3) 4M 4)0.05M



$$K_c = [\text{C}_6\text{H}_6] / [\text{C}_2\text{H}_2]^3, \quad [\text{C}_2\text{H}_2]^3 = [\text{C}_6\text{H}_6] / K_c = 1/64$$

Equilibrium concentration of acetylene, $[\text{C}_2\text{H}_2] = 0.25 \text{ mol L}^{-1}$.

- 36. At 1000K, $K_p = 1.0 \times 10^{-2} \text{ atm}$ for the reaction,**



- 1) $82.1 \times 10^{-2} \text{ mol L}^{-1}$ 2) $82.1 + 10^{-2} \text{ mol L}^{-1}$
 3) $10^{-2} / 82.1 \text{ mol L}^{-1}$ 4) $82.1 / 10^{-2} \text{ mol L}^{-1}$

Solution: Equilibrium constants are related as,

$$K_c = K_p / (RT)^{\Delta n}, \quad \Delta n = 2 + 1 - (2) = 1 \quad \text{and} \quad R = 0.0821 \text{ L-atm K}^{-1} \text{ mol}^{-1}.$$

Equilibrium constant, $K_c = 1.0 \times 10^{-2} / (0.0821 \times 1000) \text{ mol L}^{-1}$.

- 37. For the equilibrium, $2\text{SO}_3(\text{g}) \rightleftharpoons 2\text{SO}_2(\text{g}) + \text{O}_2(\text{g})$, the partial pressures of**

Since $Q > K$, the reaction proceeds in backward direction.

40. What is the extent of dissociation if the equilibrium pressure p for the system

$\text{PCl}_5 \rightleftharpoons \text{PCl}_3 + \text{Cl}_2$ are numerically 3 times to its K_p .

- 1) 0.5 2) 0.866 3) 0.25 4) 1.0

Solution: $\text{PCl}_5 \rightleftharpoons \text{PCl}_3 + \text{Cl}_2$

1	0	0	at start
1-x	x	x	at equilibrium

Total moles at equilibrium (if x is extent of dissociation) = $1 - x + x + x = 1 + x$

Partial pressure of PCl_5 , $P_{\text{PCl}_5} = \frac{1-x}{1+x}p$

Similarly, $\left(P_{\text{PCl}_3} = \frac{x}{1+x}p \right)$ and $P_{\text{Cl}_2} = \frac{x}{1+x}p$

Equilibrium constant,

$$K_p = \frac{P_{\text{PCl}_3} P_{\text{Cl}_2}}{P_{\text{PCl}_5}}$$

Substituting the values,

$$K_p = \frac{\left(\frac{xp}{1+x} \right) \left(\frac{xp}{1+x} \right)}{\frac{(1-x)p}{1+x}} = \frac{x^2 p}{(1-x)^2}$$

$$\frac{p}{3} = \frac{x^2 p}{1-x^2} \rightarrow x = 0.5 \text{ i.e Extent of dissociation of } \text{PCl}_5 = 0.5.$$

Assertion and Reason Type Questions

- 1) Both A & R are true, R is the correct explanation of A.
- 2) Both A & R are true, R is not correct explanation of A.
- 3) A is true, R is false.
- 4) Both A and R are true.

41. **A: Introduction of catalyst does not affect position of equilibrium.**

R: For a reversible reaction, presence of a catalyst influences both forward &

backward reactions to same extent.

42. **A:** For $\text{Zn(s)} + \text{Cu}^{+2}(\text{aq}) \rightleftharpoons \text{Zn}^{+2}(\text{aq}) + \text{Cu(s)}$, $\Delta G = 0$, but $K_C = 10^{37}$
R: For a process under equilibrium Gibb energy change is zero, but as this process proceeds more towards right if $K_C > 1$.
43. **A:** For $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$, $\Delta H = -Q$ KJ, low pressure yields more Ammonia.
R: According to Lechatlier's principle, increase of pressure shifts equilibrium in a direction that proceeds with increase in number of moles.
44. **A:** The degree of decomposition of PCl_5 is less at high pressures.
R: In a reversible reaction, on increasing the pressure the equilibrium shifts in the direction in which decrease in volume takes place.
45. **A:** $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$. In this equilibrium system, the yield of SO_3 is not altered in the presence of a catalyst.
R: A catalyst does not change the position of equilibrium.
46. **A:** The hydrolysis of an ester in acidic medium does not change with pressure.
R: Pressure does not show effect on equilibrium reactions taking place in solution.
47. If the degree of dissociation of PCl_5 in the reaction $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$ at equilibrium is 0.2 and if the initial number of moles of PCl_5 is one, the total number of moles present in the gaseous mixture at equilibrium is

- 1) 2.8 2) 1.2 3) 1.4 4) 1.6

Solution: $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$

1	0	0	at start
0.2	0.2	0.2	reactor formed at equilibrium
0.8	0.2	0.2	present at equilibrium

The total moles at equilibrium = $0.8 + 0.2 + 0.2 = 1.2$

48. The K_p value for $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ is 5.0 atm^{-1} . What is the equilibrium pressure of O_2 if the equilibrium pressures of SO_2 and SO_3 are equal

- 1) 0.2 atm 2) 0.3 atm 3) 0.4 atm 4) 0.1 atm

Solution: $K_p = 1/P_{\text{O}_2}$ as the equilibrium pressures of SO_2 and SO_3 are equal. Thus
 $P_{\text{O}_2} = 1/K_p = 1/5 = 0.2$

49. One mole of ethyl alcohol and one mole of acetic acid are mixed. At equilibrium 0.666 moles of ester is present. The value of equilibrium constant is

- 1) 1/2 2) 1/4 3) 2 4) 4

Solution: $\text{CH}_3\text{COOH}(\text{l}) + \text{C}_2\text{H}_5\text{OH}(\text{l}) \rightleftharpoons \text{CH}_3\text{COOC}_2\text{H}_5(\text{l}) + \text{H}_2\text{O}(\text{l})$

1.0 1.0 0 0 at start

1-0.666 1-0.666 0.666 0.666 at equilibrium

$$K_c = (0.666 \times 0.666) / (0.334 \times 0.334) = 4$$

50. In the equilibrium $\text{NH}_4\text{HS}(\text{s}) \rightleftharpoons \text{NH}_3(\text{g}) + \text{H}_2\text{S}(\text{g})$ If the equilibrium pressure is 2 atm at 80°C . K_p for the reaction is

- 1) 1atm 2) 2atm 3) 11atm² 4) 4 atm²

Solution: $\text{NH}_4\text{HS}(\text{s}) \rightleftharpoons \text{NH}_3(\text{g}) + \text{H}_2\text{S}(\text{g})$, P of $\text{NH}_3(\text{g}) + P$ of $\text{H}_2\text{S}(\text{g}) = 2$, P of $\text{NH}_3(\text{g}) = P$ of $\text{H}_2\text{S}(\text{g}) = 1$

$$K_p = P \text{ of } \text{NH}_3(\text{g}) \times P \text{ of } \text{H}_2\text{S}(\text{g}) = 1 \times 1 = 1 \text{ atm}^2$$

KEY

- 1) 4 2) 3 3) 3 4) 2 5) 4 6) 4 7) 1 8) 1 9) 3
- 10) 4 11) 1 12) 1 13) 3 14) 2 15) 3 16) 3 17) 4 18) 1
- 19) 2 20) 3 21) 2 22) 2 23) 3 24) 3 25) 2 26) 2 27) 1
- 28) 4 29) 2 30) 3 31) 1 32) 2 33) 4 34) 3 35) 1 36) 4
- 37) 2 38) 2 39) 3 40) 1 41) 1 42) 1 43) 4 44) 1 45) 1
- 46) 1 47) 2 48) 1 49) 4 50) 3